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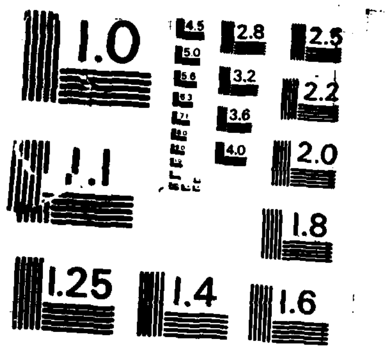

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USER'S GUIDE TO WAVEFORM DATA ACQUISITION IN THE PULSED LASER LABORATORY OF THE LASER HARDENING BRANCH

David J. Kosan
Laser Hardened Materials Branch
Electromagnetic Materials Division

June 1986

Interim Technical Report for Period June 1984 - December 1984

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This report contains an overview of the computer facilities associated with the Pulsed Laser Laboratory of the Materials Laboratory's Electromagnetic Materials Division. Included are brief descriptions of hardware and software configurations, general operating procedures and documentation of currently implemented programs.

The purpose of this report is to serve as a guide for new users of the Pulsed Laser Laboratory. Those wishing to become experts in the details of programming and hardware interconnection of our systems should consult some of the more advanced entries cited in References.

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Summary

At present the Tektronix systems are installed and operational. The streak camera has just recently arrived and research personnel are still becoming familiar with its operation. Research personnel are currently developing acquisition and control programs on an as-needed basis. These programs will be documented in additional appendices. Also, a laser-beam diagnostics stage, which is being characterized at this time, will provide a permanent stage in which the power, temporal and spatial profile of the laser output can be determined.

Future work will concentrate on programming and interfacing the streak camera. There will also be future equipment updates consisting of the installation of a high-resolution color terminal and 10-megabyte hard disk drives.

FOREWORD

This report describes an in-house study conducted by personnel of the Laser Hardened Materials Branch, Electromagnetic Materials Division, Air Force Wright Aeronautical Laboratories, Wright-Patterson Air Force Base OH 45433 under Project 2422, Task 242204, Work Unit 24220401. The work reported herein was performed during the period June 1984 through December 1984 by David J. Kosan. The report was released on 17 December 1984.

The author wishes to thank Les Aeder of Tektronix, Inc. for his technical advice on numerous occasions.

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SECTION I

SYSTEM DESCRIPTION

1. SIGNAL ACQUISITION AND PROCESSING

The Pulsed Laser Laboratory's data acquisition system consists of highly complex hardware and software components integrated into a stand-alone unit which one may easily implement to acquire and process signals from extremely fast transient events (about 2 picoseconds). This system can greatly enhance research productivity through flexibility in designing experiments and rapid handling of large volumes of data.

2. HARDWARE

First, the heart of the system is a DEC(1) PDP-11/23 16-bit microcomputer which functions as the contoller. All commands and operations originate and terminate through it. Second, there are two Tektronix(2) 7912AD programmable digitizers which functionally may be viewed as fast oscilloscopes. These are the actual instruments which acquire and digitize the signals. Third, there are two DEC(1) RXV21 8-in. floppy disk drives for program and data storage. A Hamamatsu streak camera provides the capability to capture very fast optical events (down to about 2 picoseconds), and implements a wide range of image processing functions on these captured events. Finally, there are peripheral devices that give the system its unique capabilities and convenience of operation. These include an operator's terminal with a high-resolution graphics display, line-printer, X-Y plotter, and a storage display copier.

3. SOFTWARE

The system software consists of a large set of small subprograms or "modules" which can be implemented together to give extremely powerful capabilities. In fact, the progam modules are the entities which integrate all the hardware and define the system's properties. With these software modules one has the capability to acquire, store, digitize, convolve, and display waveforms and other data. These operations can be used separately; however, their real power is attained by using them together.

SECTION II

HARDWARE

1. MAJOR COMPONENTS

The major system components are the DEC PDP-11/23 microcomputer, two Tektronix 7912AD programmable digitizers, Hamamatsu streak camera, and the DEC RXV21 dual disk drive. Figure 1 is a schematic of both major system and support components.

1.1 DEC PDP-11/23 Microcomputer

The DEC PDP-11/23 is a 16-bit high-performance computer which can control four megabytes of main memory with its 22-bit addressing. The PDP-11/23 utilizes the latest MOS/LSI (metal-oxide semiconductor/large-scale integration) technology in its construction. Communication between the CPU (central processor unit), memory, and peripherals is accomplished through DEC's industry standard LSI-11 bus. The controller boards for the IEEE-488 instrument-controller interface and the line-printer interface are also connected to the PDP-11/23 via the LSI-11 bus.

1.2 Tektronix 7912AD Programmable Digitizer

The Tektronix 7912AD programmable digitizer is a wide-bandwidth signal acquisition instrument which is configured to interface through the IEEE-488 standard bus.

The 7912AD can operate either in the TV mode or digital mode. In the TV mode, the 7912AD converts the input signal into a composite video output which is displayed on a TV monitor. In the digital mode, single-shot or repetitive signals are digitized and stored to allow internal signal processing or output via the IEEE-488 interface bus. Operation in either mode provides capabilities to acquire signals with bandwidths from dc to 1 GHz. This is equivalent to a more conventional digitizer with a sampling rate of 100 GHz. The effective time-base window of the 7912AD can be selected from 5 nanoseconds to 10 milliseconds.

The operation of the 7912AD may be compared with that of a conventional oscilloscope. The input signal is coupled to a vertical deflection amplifier while horizontal sweep is controlled by a programmable time base. Although the vertical and horizontal deflections in the 7912AD are similar to a conventional oscilloscope, other features of operation are decidedly different.

In an oscilloscope an electron beam is used to write a trace on a phosphor screen inside a CRT (cathode ray tube). However, in the 7912AD the CRT is replaced by a scan converter tube. The input signal is written on a silicon diode matrix and read from this matrix as in a vidicon TV

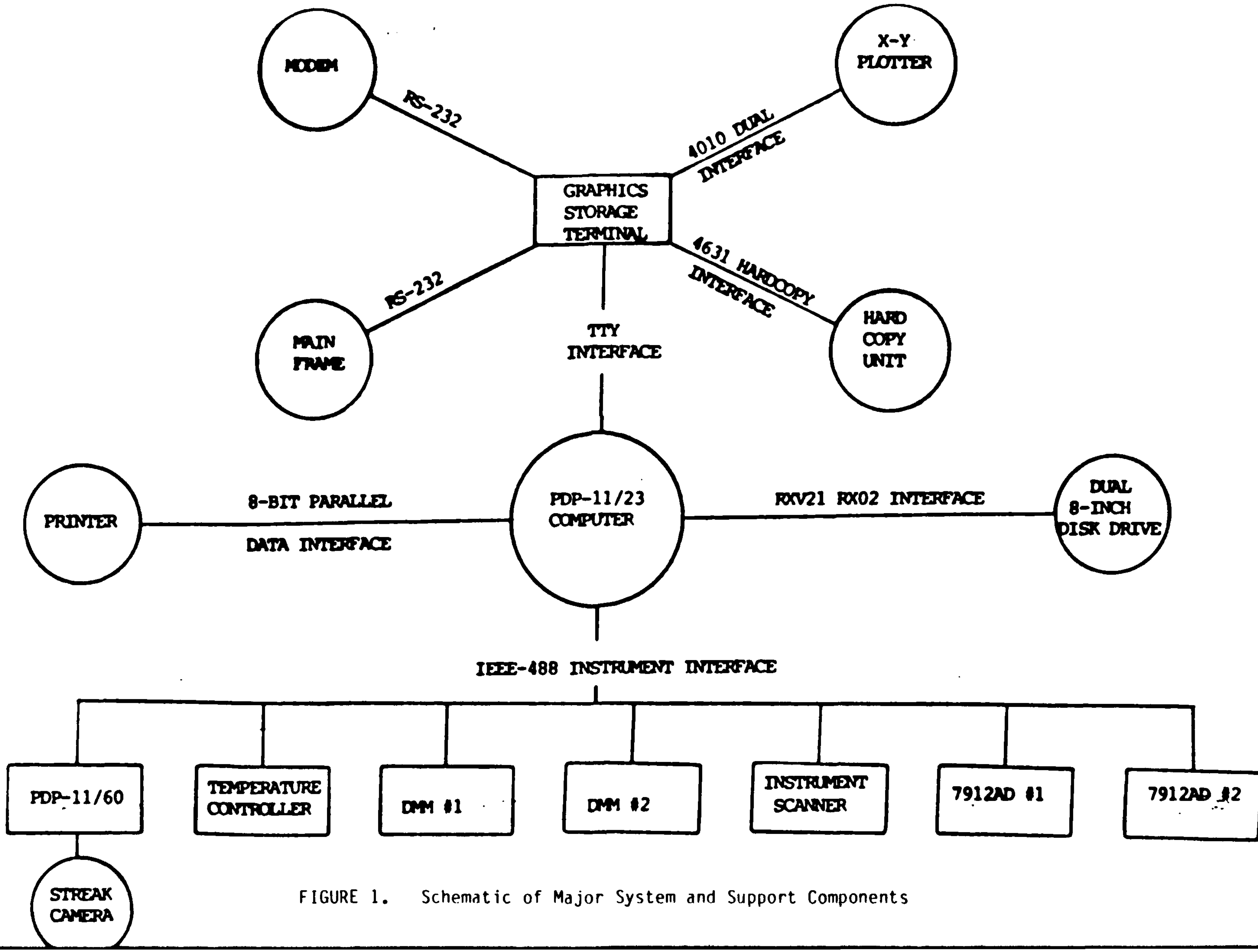

FIGURE 1. Schematic of Major System and Support Components

camera. The scan converter is an electron tube with one electron gun at each end of the tube and a silicon target chip midway between the two guns. The target is composed of an array of diodes formed on an n-type silicon wafer. During operation the target substrate is held at a positive potential relative to the reading gun cathode. The target is scanned continuously by the reading beam which charges each diode toward a more negative potential to reverse-bias it.

When the time base is triggered, a ramp voltage is applied to the horizontal deflection plates of the writing gun to scan the beam across the target thus producing a trace. At the same time the input signal is applied to the vertical plates to change the vertical displacement of the trace according to the amplitude of the input signal.

A 10,000-volt potential accelerates the electrons from the writing gun into the target array. Each colliding electron creates approximately 2780 electron-hole pairs, which, after accounting for losses, provides an effective gain of 2,000. Each of the holes that does not recombine diffuses through the target and drifts across the depletion region at the p-n junction of a diode, causing the diode to conduct and hence discharge. When the reading beam next scans the target array, those diodes that have not been discharged by diffusing holes do not charge. Therefore, no current is corresponding to these locations. However, the diodes that have been discharged do produce a current when scanned by the read beam. It is this current which is detected and processed for display on the TV monitor. The ability to capture rapid events arises because the signal can be written upon the target array at a very high speed and in real time. The captured signal can then be read off at a more convenient rate.

1.3 DEC RX02 Floppy Disk Drives

The RX02[3] is a low-cost random-access mass-memory device that stores data in fixed-length blocks on 8-in. flexible diskettes with pre-formatted industry standard headers. The unit consists of two flexible disk drives, a single read/write electronics module, a microprogrammable controller module, and a power supply enclosed in a rack-mountable self-cooled chassis.

The recording density is either single or double density. In single density each diskette can hold 256 kilobytes of data while in double density 512 kilobytes of data can be stored on each diskette. The RX02 interfaces with most IBM-compatible[4] devices when single density data recording is used. As currently configured, the RX02 can both read and write in double density format and read single density formatted diskettes. The diskettes can be used for the storage of system software, command packages, programs, and data.

1.4 Hamamatsu Streak Camera

The Hamamatsu C1587 Universal Temporal Disperser[5] is a state-of-the-art streak camera which can be operated in one of two modes: ultra-

high-speed sweep or slow-speed sweep, depending on which plug-in is implemented. By using the high-speed plug-in (M1952) the C1587 operates as an ultra-fast single-sweep streak camera with a temporal resolution better than 2 ps. The slow-speed plug-in (M1953) provides a temporal resolution better than 100 ps.

Operation of the streak camera can be described as follows. Light from the event being studied is directed onto the slit aperature of the input optics. The input optics then direct the slit image onto a photocathode where it is converted to an electron image. Electrons emitted from the photocathode are then accelerated toward the positive accelerating mesh. After passing the acceleration mesh the electrons enter the deflection field set up by the sweep electrodes. This deflection field is created by a high-speed ramp voltage being applied to the sweeping electrodes after reception of a triggering signal. The swept electron image is then projected onto a micro-channel plate (MCP) where the image is electronically amplified and then imaged onto a phosphor screen producing a light image. This image is viewed by a SIT camera which transmits its output to an image-processing unit which can perform extensive image processing and/or storage functions.

With this instrument one has the capability to acquire extremely fast events and simultaneously record temporal, spatial, and intensity characteristics of optical phenomenon. Since this instrument is controlled with a DEC PDP-11/60 microprocessor and has several RS-232 data ports it can be directly interfaced to the Tektronix system providing a consolidated data acquisition system.

2. SUPPORT COMPONENTS

Support components include those devices which are necessary to use the major system or to increase its utility.

2.1 Display Terminal

The Tektronix 4012 display terminal[6] allows the exchange of information between the operator and the computer. Inputs by the operator to the computer are made through the terminal keyboard while data from the computer can be displayed on the terminal screen. The screen is a storage screen much like those found in many oscilloscopes.

Terminal utility is not limited to writing on the screen. It can also perform a host of other functions in response to control character commands. Some of these functions include controlling the display format, switching modes, and controlling output from the terminal screen.

The terminal consists of two principal parts: the display unit and the pedestal stand. The display unit houses the storage display tube, keyboard, and their associated circuits. The pedestal unit contains the terminal circuits, power supply, and interface cards.

2.2 Printer

The Tektronix 4643 Printer[7] is a general purpose, medium-speed serial impact printer. It uses a dual column 14-wire matrix printing head which moves horizontally and prints in both directions. The data-transfer rate is selectable from 110 to 9600 baud. The printer can produce standard computer printouts of raw experimental data or results of extensive computations by the computer. It is useful for producing listings of programs, data, and system information for permanent reference.

2.3 Interactive Plotter

The Tektronix 4662 Interactive Plotter[8] is an intelligent flat-bed plotter. It uses an electrostatic hold-down system to draw or print on paper or transparent film as large as 11 in. by 17 in. The plotter has RS-232-C and IEEE-488 interfaces. Data input to the plotter is internally buffered (2 kilobytes) to optimize data transfer. The plotter can also be used as a digitizer to convert any drawing or graph into computer code for further processing.

2.4 Hard Copy Unit

The 4631 Hard-Copy Unit[9] makes permanent high contrast copies from the storage display terminal. A "photograph" of the display terminal screen is imprinted on dry silver paper when a toggle switch on the terminal bezel is activated. The silver paper print is photo sensitive and must not be exposed to high-intensity light sources for extended periods. Solutions to this problem are to make a photocopy of the print or store the print in an envelope or closed cabinet.

2.5 Voltage Recording Subsystem

2.5.1 Instrument Scanner

The Keithley Model 705 Scanner[10] is a programmable IEEE-488 compatible instrument scanner. The basic unit can accommodate two plug-in scanner cards, each having different pole configurations. In the one-pole configuration the card allows 20 channels of signal connections while the four-pole configuration allows 10 channels of connections (for four-wire ohms).

The controls on the front panel allow opening selected channels, closing the channels, scanning between selected channels, selectable scan rate, and mode. From the front panel, 13 internal programs are accessible which can select the primary address and dwell time, store a relay set-up, recall the stored relay set-up, control the digital I/O port, switch from International to American date format, control internal stop/start, and select one-, two-, or four-pole measurement modes. The scanner can be used to obtain outputs from a large array of instruments and these outputs can be directly fed to the system main computer for further processing or storage.

2.5.2 Digital Multimeters

The voltage recording subsystem includes two Keithley Model 195 Digital Multimeters[11] (DMM) that are IEEE-488 compatible. These have three modes of operation: as a bench instrument, front panel programmable, and IEEE-488 driven. The Model 155 DMM is capable of d-c voltage measurements from 10 nanovolts to 1000 volts, through six ranges, two-pole and four-pole resistance measurements between 10 micro-ohms and 20 megohms, and current measurements from 100 pico-amperes to 2 amperes. The a-c measurements can also be made with an a-c voltage range of 1 microvolt to 700 volts and an a-c current range between 1 nanoampere and 2 amperes. The Model 195 DMM is equipped with a host of front panel programs to aid operation, and is completely controllable through the IEEE-488 interface bus.

2.7 Instrument and Communication Interfaces

Various interfacing cards are necessary for proper connection of all system and subsystem components. In most operation modes these interfaces are transparent to the user since the detailed interface commands are handled by the system software.

The IEEE-488 circuit board[12] allows standard communication between the PDP-11/23 computer and up to any 15 IEEE-488 compatible instruments. There is provision for up to four interface boards, providing control for 60 different instruments.

The data communications interface[13] provides the link between the computer and the display terminal. This device also allows communication between the terminal and other mainframe computer systems by use of a modem. The interface tasks include parallel to serial conversion for transmitting data and vice versa for receiving data, voltage level conversions, timing management, and modem control. This interface is RS-232-A or RS-232-C compatible and can operate in full or half duplex modes. Baud rates for transmitting and receiving data are selectable between 50 and 19,200.

A third interface known as the 4010 dual interface[14] permits communication between the display terminal and the X-Y plotter or any other device which communicates through a TTY-type interface.

SECTION III

SOFTWARE

1. Tektronix Packages

Tek (Tektronix) SPS (Signal Processing System) BASIC[15] is a system software package that combines the general purpose, easy-to-use structure of traditional BASIC languages with a wide selection of sophisticated commands for control of instruments, and the acquisition, processing, storage, and display of waveform data.

Tek SPS BASIC software is modular in design. Modular means that many of the program code listings which are used by the computer to implement various commands are not kept in the computer main memory, but are loaded from disks when they are used and removed when they are not used. This allows efficient use of available memory and the ability to expand or modify code listings which make up each command file. The modular construction of SPS BASIC allows the freedom to design a signal acquisition and processing system to meet individual needs rather than a general need.

The following section will discuss the special software packages which are currently implemented and the individual command modules which constitute the packages.

1.1 BASIC Language with SPS

The BASIC used by the Tek SPS system is very similar to most other BASIC languages but with many special enhancements.

In general, BASIC is an interpretive language. As a line is typed on the terminal, the line is being stored in the computer's main memory sequentially according to line number. The entering order of lines does not matter because the interpretive operating system takes one line at a time from memory in line number order and then executes the commands in that line.

The BASIC operating system is the software that handles all the computer operations and overhead so that most of the "housekeeping" tasks are transparent to the user. The operating system is in resident memory, i.e., it is always present and is not loaded and unloaded from disk as are other software modules.

SPS BASIC has some special features which increase the data acquisition and processing capabilities of the system. In particular, many functions and commands have been added which handle large arrays of data. Most of the general BASIC commands have been enhanced to allow them

to operate on not only single-valued functions but also on one- and two-dimensional arrays. For example, addition, multiplication, and trigonometric functions of large arrays can be executed by a single BASIC command, greatly facilitating the development of programs for data processing. These features combined with the other software packages described below permit complex data handling operations to be effectively programmed and implemented.

1.2 IEEE-488 Interface Software

The major instrument interfacing capability of the system is the IEEE-488 interfacing software. The IEEE-488 is a national standard for general purpose instrument interfacing, by which two or more instruments that comply with this standard may be connected and operated together. The software allows the user to control any of the instruments in the interface in a very simple manner, while all the housekeeping tasks are performed by the system so that they remain transparent to the user.

There are presently two IEEE-488 software packages: IEEE-488 "High Level Instrument Driver" and IEEE-488 "Low Level Instrument Driver."

1.2.1 High Level Driver

The "High Level Instrument Driver" or "INS" is designed to control small systems composed of Tek instruments. The commands in general are very powerful. Most all of the tedious housekeeping operations are performed by the software as they are needed, thus freeing the programmer from these tasks. In general, the High Level commands have a very descriptive format which makes the code easy to read and interpret.

1.2.2 Low Level Driver

The limitations of the INS are that they are only for small Tek systems and have limited flexibility. The Low Level Driver is more difficult to use because of its general nature; however, it allows one to interface many more instruments than the INS, including those made by other manufacturers. With the Low Level Driver the programmer has complete control of the interface, so that even some "nonstandard" instruments may be accommodated.

1.3 7912AD Commands Package[16,17]

While the IEEE-488 interface is very useful for communication with the 7912AD digitizer, it leaves the acquired data in a relatively primitive form. Some data enhancement capabilities are built into the 7912AD, including removal of target defects from data and signal edge processing. Further enhancements are provided by special nonresident commands contained in Tek SPS BASIC. These command modules allow: convenient graphing of raw data without preprocessing (ADPLOT); reduction of raw data to edge data (EDGEAD); computation of a zero reference value (ZREF);

rejection of target defects (REJECT); geometry correction for CRT-induced distortion (INSTAD and MAPAD); and full reduction of the acquired waveform to a calibrated array consisting of one floating-point vertical value for every horizontal address (NORMAD). An additional command (ADLOG) allows one to acquire and digitize a series of waveforms at high rates and store these directly onto a hard disk for later processing.

1.4 Signal Processing Package

The Signal Processing Package[18] contains seven nonresident Tek BASIC commands which can be used on data arrays and waveforms. The following is an outline of these commands:

1. Convolution (CONVL) performs a noncyclic discrete convolution operation on two source arrays or waveforms.
2. Correlation (CORR) performs a noncyclic discrete auto- or cross-correlation on two source arrays or waveforms.
3. Differentiation (DIFF) performs a differentiation of a source array or waveform.
4. Integration (INT) performs an integration of a source array or waveform.

5,6 Fast Fourier Transforms (RFFT, RFFTI) performs a fast Fourier transform on an array or waveform. These commands can also perform inverse Fourier transforms.

7. Polar (POLAR) performs a rectangular-to-polar conversion of the real and imaginary components of arrays or waveforms as returned by the RFFT command.

1.5 Graphics Package

The Tektronix Graphics Package[19] commands provide the user extensive graphics capabilities. These are single high-level commands which can produce finished graphs and plots of array and waveform data. There are also many low-level commands which give the user control of almost every aspect of the graphics capabilities of the system. In general, any type of drawing or graph that can be produced by pen can be constructed on the display terminal or the X-Y plotter.

2. RT-11 Operating System

At present the computer system can also be used as a stand-alone development station. This is done by implementing DEC's RT-11 V04 operating system[20] which is totally independent of Tek SPS BASIC. RT-11 is DEC's smallest real-time and program-development operating system for the PDP-11 family of minicomputers. RT-11 is designed to be small, efficient, reliable, and easy to use.

REFERENCES

1. Digital Equipment Corporation, Maynard MA 01754.

2. Tektronix, Inc., PO Box 1700, Beaverton OR 97075.

3. RX02 Floppy Disk System Users Guide, Digital Equipment Corporation.

4. International Business Machines, Danbury CT 06810.

5. Instruction Manual for Temporal Disperser C1587, Hamamatsu, Inc., 40 Bearhill Road, Waltham MA 02254.

6. 4012 Computer Display Terminal, Tektronix, Inc. (Feb 1982).

7. 4643 Printer Owners Manual, Tektronix, Inc. (Aug 1983).

8. 4662 Digital Plotter Operators Manual, Tektronix, Inc. (Apr 1982).

9. 4631 Hard Copy Unit Users Manual, Tektronix, Inc. (Aug 1982).

10. Instruction Manual -- Model 705 Scanner, Keithley Instruments, Inc., 28775 Aurora Road, Cleveland OH 44139.

11. Model 195 Instruction Manual, Keithley Instruments, Inc., 28775 Aurora Road, Cleveland OH 44139.

12. CP4100/IEEE-488 Interface Instruction Manual, Tektronix, Inc. (Jan 1983).

13. Optimal Data Communications Interface, Tektronix, Inc. (Jan 1982).

14. 4010 Dual Interface Instruction Manual, Tektronix, Inc. (Apr 1982).

15. Tektronix SPS Basic V02/V02XM System Software Instruction Manual, Tektronix, Inc., (1983).

16. 7912AD Commands Package Instruction Manual, Tektronix, Inc. (Jul 1982).

17. 7912AD Programmable Digitizer Operators Manual, Tektronix, Inc. (Aug 1983).

18. Signal Processing Package Instruction Manual, Tektronix, Inc. (Aug 1983).

19. Graphics Package Instruction Manual, Tektronix, Inc. (Apr 1983).

20. RT-11 System User's Guide, Digital Equipment Corporation (1980).

APPENDICES

Appendix A

PROGRAM IMPLEMENTATION INSTRUCTIONS

1. General

In order to use any of the data acquisition or processing programs one must first set up the system. Before turning on the power, a few precautions must be taken. First, make sure that the main intensity and graticule intensity on the 7912AD digitizers are turned down (counter-clockwise). Second, turn off the vertical amplifier and turn the vertical gain to its minimum position. By following these precautions, damage to the 7912AD digitizers may be prevented.

Next, make sure the operating system disk is loaded into the left-hand drive (DY0:) and the program/data disk is loaded into the right-hand drive (DY1:).

The normal positions for the front bezel switches on the computer are: "RESET," down; "HALT," up; "AUX," up. The display terminal should now be turned on and allowed to warm up for approximately 10 seconds after which the screen should be cleared by pressing the "**PAGE**" key.

Now the system can be turned on by pressing the power switch located on the upper-right corner of the cabinet. The system will then perform a memory test (after which the "**START?**" prompt will be displayed). The Operator should respond by typing **DY** followed by a return. The system will then display current configuration information, load the operating system and apply software patches. After successful completion of this sequence, a "**READY**" prompt will be printed informing the user that the system is ready to accept commands.

To load and run a program, simply type: **OLD DY1:"PROGRAM NAME,"** "**RUN.**" Any further instructions needed to run the program will be provided by the program itself. If at any time the system crashes it can be restarted by toggling the "Restart" switch on the computer front bezel. If the program stops and the "**READY**" prompt appears, the program can be restarted by typing "**RUN**" again. In some cases a program stoppage may be severe enough to require the computer to be reset (as in the case of a system crash).

To turn the system off one should again apply the same precautions for turning on the 7912AD digitizer, i.e., turn down the main and graticule intensities, minimize the vertical amplifier gain, and turn the input

selection switch to the "Off" position. Then simply press the main power switch. The display terminal should then be cleared by pressing the "PAGE" key and finally turned off.

2. Start-Up Summary

- o Main intensity on 7912AD turned down (counterclockwise).
- o Graticule intensity on 7912AD turned down (counterclockwise).
- o Select the "off" position for the input coupling on the vertical amplifier.
- o Turn the vertical gain to its minimum position (counter-clockwise).
- o Load operating system into **DY0:**
- o Load program/data disk into **DY1:**
- o Select front panel switches on computer ("RESET," down; "HALT," up; "AUX," up).
- o Turn on power.
- o Respond to **START?** by typing **DY.**
- o Load desired program by typing: **OLD DY1:**"xx....xx"
- o Run program by typing **RUN.**

Appendix B

PROGRAMS

Program: LAB2.BAS

1. Introduction

This program provides the capability to acquire five sets of two simultaneous waveforms from two 7912AD transient digitizers. If the repetition rate of the waveforms is less than 4 Hz, the program will capture each waveform in a contiguous manner. The captured waveforms are then graphed on the operator's terminal for viewing.

In order to provide the high data-transfer rates required by these operations certain new programming techniques were developed. These include nonconventional use of the repetitive digitize command and synchronized direct-memory-access transfer of raw data from the 7912AD data buffers to the computer's extended array memory.

In the Pulsed Laser Laboratory experiments we want to obtain a set of waveforms which represent the incident and reflected or transmitted laser radiation from a target sample. Further, it is often necessary to capture multiple waveforms in a contiguous manner so pulse-to-pulse interactions can be resolved. This requires the ability to simultaneously capture more than one set of waveforms at high enough rates to form an array of contiguous sets.

To attain this performance each 7912AD is configured to capture a waveform from its respective detector. Then each 7912AD sequentially accesses the computer's extended array memory and initiates a direct-memory-access data transfer. This must be done as quickly as possible so the digitizers can be reset to acquire the next set of waveforms. This type of instrument interaction is accomplished by simultaneously putting the repetitive digitize command into both 7912ADs and then issuing a binary-read command to each digitizer to initiate binary DMA data transfer over the IEEE-488 instrument interface.

The required software packages are: SPS BASIC
7912AD Commands Package
SPS Graphics Package

General Operation Instructions

For general implementation of the data-acquisition system it is necessary to know how to properly turn the system on and initiate computer cooperation.

Procedure

1. Turn on the Operator's console. The switch is located under the keyboard and to the rear. Allow the display screen to warm up for approximately 10 seconds. During this time the terminal will begin to display bright patches which can be cleared by pressing the **PAGE** key.

2. Load the operating system disk in the left-hand drive and the program data disk in the right-hand drive. Caution should be exercised to avoid damaging the diskettes.

3. Check to make sure the control switches on the bezel of the computer are properly selected: RESET, down; HALT, up; AUX, UP.

4. If the 7912AD digitizers are to be used, make certain that the write-beam and graticule intensities are turned down (all the way counterclockwise), the vertical amplifier gain is at the minimum setting, and the input coupling is in the Off position.

5. Turn the 7912AD display monitor power switches to the ON positions.

6. Turn on the main power switch located on the upper right-hand corner of the cabinet.

7. Turn on each 7912AD by toggling the ON/OFF switch on the front panels.

8. On the Operator's terminal the **START?** prompt should be displayed. Respond to this prompt by typing **DY** and then the **RETURN** key. This reply tells the computer that the operating system is located on the left-hand floppy disk drive.

9. The operating system will now be booted. After a short time various system information will be displayed and software patches will be applied. Then the **READY** prompt will be displayed informing the Operator that the system is now ready to accept commands in accordance with the Tektronix SPS BASIC operating system.

10. To run a program, type: **RUN DY1:"PROGRAM NAME"** and then press the **RETURN** key. It is assumed that the program is stored on the right-hand disk, i.e., **DY1:**. If the program is on the system disk type **DY0:** instead of **DY1:**.

11. To turn the system off, first turn down the 7912AD write-beam and graticule intensities. Then turn the vertical amplifier gain to the minimum setting and turn the input coupling to the Off position. Now the main power switch can be turned off. The display terminal should be paged before being turned off.

2. Program Listing Description

Lines 5-15

These lines clear the display screen, inform the user that the program is running, and then loads most of the necessary nonresident commands that will be used. The system build command was used to change the maximum number of nonresident commands that can be used at any one time.

Lines 20-30

Here the Operator is instructed to turn on the 7912ADs and monitors.

Lines 35-55

In these lines all the general-purpose waveforms are defined.

Lines 60-75

Line 60 sets the interface time-out period to 6 seconds. This defines the time which the interface will wait for a response after a command has been issued by the controller instrument.

Lines 65-75

These lines assign the proper values for the IEEE-488 listen, talk, and secondary addresses to the Variables LA, TA, and SA, respectively.

Lines 80-115

These lines of code perform target defect removal. For each digitizer the interface-clear and selective-device-clear commands are issued first, totally clearing and resetting the instruments and bus of any communication traffic. The digitize-defects command is then issued 64 times and any defects that are registered at this time are flagged and hence removed from any waveforms by the defect-on command.

Lines 120-150

Here the 7912ADs are put into the TV and local modes so that the Operator can acquire zero reference ground traces. The wait command stops program execution to allow the Operator to make the necessary adjustments. Pressing any key on the keyboard causes execution to continue.

Lines 155-195

This loop actually acquires the zero reference value by making use of Subroutine 1000. The zero reference value for each digitizer is then assigned to its respective variables, Z1 or Z2. The go-to-local command is also issued to each instrument to allow front panel adjustments.

Lines 200-215

Here the Operator is instructed to unground the vertical amplifiers and establish the display of the desired signal.

Lines 220-235

These lines of code are used to read the vertical and time-base settings of the plug-ins. These values are later used to plot the acquired waveforms.

Line 500

This line of code calls Subroutine 300 which is the waveform acquisition routine.

Lines 501-660

In this block of code the pointer and edge data arrays are assigned to waveforms and through the implementation of Subroutines 4000 and 5000 these waveforms are plotted on the Operator's terminal. After plotting all the acquired waveforms the program returns to Line 200 and is ready to acquire a new set of signals.

Lines 1000-1260

This is the subroutine used to acquire the waveform data; i.e., the pointer array, vertical edge array, and the amplifier and time-base settings.

Lines 2000-2150

This is a general raw data-array acquisition subroutine. It is used whenever the pointer or vertical data arrays are read from a digitizer. It acquires the data into the properly dimensioned array QQ.

Lines 3000-3160

These lines of code are where the repetitive acquisition of the waveforms occurs. All pointer and vertical data arrays are deleted. Then the command is simultaneously issued to both digitizers. Next the IEEE-488 interface is configured for DMA data transfer. At this point both instruments are set up to acquire waveforms and acquisition is initiated by the first signal which triggers the time base. Waveform acquisition is initiated by a series of read-binary commands which alternately read the captured pointer and vertical data arrays from each instrument in an alternating fashion. If the signal repetition rate is 20 Hz or less the program will acquire each signal in a contiguous manner.

Lines 4000-5000

These two subroutines are called in Lines 500-650. They are used to implement the NORAD command, graph the waveforms, and then delete the waveform arrays to allow the next waveform to be graphed. Subroutines 4000 or 5000 are used depending on which digitizer the waveform was acquired so that the proper zero reference and plug-in setting are used.

```
  5 PAGE\
    PRINT "PROGRAM IS RUNNING"
 10 LOAD "GPI.SPS","PAGE.SPS","WAIT.SPS","PRINT.SPS","SIFLIN.SPS"
 15 LOAD "GET.SPS","IFDTM.SPS","GRAPH.SPS","INPUT.SPS","ZREF.SPS"
 20 PAGE\
    PRINT "TURN ON ALL MONITORS AND BOTH 7912ADS."
 25 PRINT\
    PRINT "PRESS SPACE-BAR TO CONTINUE."
 30 WAIT
 35 PAGE\
    PRINT "RUNNING"
 40 INTEGER A(511),B(511)
 45 WAVEFORM WA IS A,IA,HA$,VA$
 50 WAVEFORM WB IS B,SB,HB$,VB$
 55 WAVEFORM WC IS C(511),SC,HC$,VC$
 60 SIFTO @0,3000
 65 LA=32
 70 TA=64
 75 SA=96
 80 PAGE\
    PRINT "DIGITIZING CRT TARGET DEFECTS 64 TIMES."
 85 FOR N=0 TO 1
 90   SIFLIN @0,"IFC"
 95   SIFCOM @0,LA+N,SA,"SDC"
100   PUT "DIG DEF,64" INTO @0,LA+N,SA
105   SIFTO @0,6000
110   PUT "DEF ON" INTO @0,LA+N,SA
115 NEXT N
120 PUT "MODE TV" INTO @0,LA,SA
125 PUT "MODE TV" INTO @0,LA+1,SA
130 PAGE\
    PRINT "TO ACQUIRE WAVEFORM REFERENCE TRACES GROUND THE"
135 PRINT\
    PRINT "VERTICAL PLUG-INS, ADJUST INTENSITIES AND THEN"
```

```
140 PRINT\
    PRINT "PRESS THE SPACE-BAR TO CONTINUE."
145 SIFCOM @0,LA,SA,"GTL"\
    SIFCOM @0,LA+1,SA,"GTL"
150 WAIT
155 PAGE\
    PRINT "RUNNING"
160 FOR N=0 TO 1
165   GOSUB 1000
170   EDGEAD QQ,P,A,B
175   ZREF A,B,ZR
180   IF N=0 THEN Z1=ZR
185   IF N=1 THEN Z2=ZR
190   SIFCOM @0,LA+N,SA,"GTL"
195 NEXT N
200 PAGE\
    PRINT "TO ACQUIRE WAVEFORMS UNGROUND VERTICAL PLUG-INS"
205 PRINT\
    PRINT "ESTABLISH WAVEFORMS, ADJUST INTENSITIES AND"
210 PRINT\
    PRINT "THEN PRESS THE SPACE-BAR TO CONTINUE."
215 WAIT
220 FOR N=0 TO 1
225   GOSUB 1120
230   IF N=1 THEN GOTO 235
231   SQ=SP\
      VT=VS\
      HQ$=HP$\
      VQ$=VP$
235 NEXT N
500 GOSUB 3000
501 PUT "MODE TV" INTO @0,LA,SA
502 PUT "MODE TV" INTO @0,LA+1,SA
505 DELETE WP
510 WAVEFORM WP IS P0,SQ,HQ$,VQ$
```

```
515 EDGEAD Q0,WP,WA,WB
520 GOSUB 4000
525 WAVEFORM WP IS P1,SP,HP$,VP$
530 EDGEAD Q1,WP,WA,WB
535 GOSUB 5000
540 WAVEFORM WP IS P2,SQ,HQ$,VQ$
545 EDGEAD Q2,WP,WA,WB
550 GOSUB 4000
555 WAVEFORM WP IS P3,SP,HP$,VP$
560 EDGEAD Q3,WP,WA,WB
565 GOSUB 5000
570 WAVEFORM WP IS P4,SQ,HQ$,VQ$
575 EDGEAD Q4,WP,WA,WB
580 GOSUB 4000
585 WAVEFORM WP IS P5,SP,HP$,VP$
590 EDGEAD Q5,WP,WA,WB
595 GOSUB 5000
600 WAVEFORM WP IS P6,SQ,HQ$,VQ$
605 EDGEAD Q6,WP,WA,WB
610 GOSUB 4000
615 WAVEFORM WP IS P7,SP,HP$,VP$
620 EDGEAD Q7,WP,WA,WB
625 GOSUB 5000
630 WAVEFORM WP IS P8,SQ,HQ$,VQ$
635 EDGEAD Q8,WP,WA,WB
640 GOSUB 4000
645 WAVEFORM WP IS P9,SP,HP$,VP$
650 EDGEAD Q9,WP,WA,WB
655 GOSUB 5000
660 GOTO 200
1000 REM SUB TO ACQUIR WAVEFORM DATA
1010 INTEGER P(511)
1020 WAVEFORM WP IS P,SP,HP$,VP$
1030 PUT "DIG DAT" INTO @0,LA+N,SA
1040 PUT "READ PTR,VER" INTO @0,LA+N,SA
```

```
1050 GOSUB 2000
1060 P=QQ
1070 GOSUB 2000
1120 PUT "MODE TV" INTO @0,LA+N,SA
1130 PUT "HS1?" INTO @0,LA+N,SA
1140 GET A$ FROM @0,TA+N,SA
1150 SP=VAL(SEG(A$,5,LEN(A$)-1))
1160 SP=SP/51.2
1170 PUT "VS1?" INTO @0,LA+N,SA
1180 GET A$ FROM @0,TA+N,SA
1190 VS=VAL(SEG(A$,5,LEN(A$)-1))
1200 PUT "HU1?" INTO @0,LA+N,SA
1210 GET A$ FROM @0,TA+N,SA
1220 HP$=SEG(A$,5,LEN(A$)-1)
1230 PUT "VU1?" INTO @0,LA+N,SA
1240 GET A$ FROM @0,TA+N,SA
1250 VP$=SEG(A$,5,LEN(A$)-1)
1260 RETURN
2000 REM SUB TO READ DATA ARRAY
2010 DELETE QQ
2020 IFDTM @0,"UNP"
2030 GET X FROM @0,TA+N,SA
2040 IF CHR(X)<>"%" THEN STOP
2050 IFDTM @0,"PAK","HBF"
2060 GET CW FROM @0,TA+N,SA
2070 CW=(CW-1)/2-1
2080 IF CW=-1 THEN GOTO 2110
2090 INTEGER QQ(CW)
2100 GET QQ FROM @0,TA+N,SA
2110 IFDTM @0,"UNP"
2120 GET X FROM @0,TA+N,SA
2130 GET X FROM @0,TA+N,SA
2140 IF CHR(X)<>";" THEN STOP
2150 RETURN
3000 PEM SUB TO ACQUIRE USING REP
```

```
3010 DELETE P0,P1,P2,P3,P4,P5,P6,P7,P8,P9
3020 DELETE Q0,Q1,Q2,Q3,Q4,Q5,Q6,Q7,Q8,Q9
3030 PUT "REP 5" INTO @0,LA,SA;LA+1,SA
3040 IFDTM @0,"PAK","HBF"
3050 READBI P0,Q0 FROM @0,TA,SA
3060 READBI P1,Q1 FROM @0,TA+1,SA
3070 READBI P2,Q2 FROM @0,TA,SA
3080 READBI P3,Q3 FROM @0,TA+1,SA
3090 READBI P4,Q4 FROM @0,TA,SA
3100 READBI P5,Q5 FROM @0,TA+1,SA
3110 READBI P6,Q6 FROM @0,TA,SA
3120 READBI P7,Q7 FROM @0,TA+1,SA
3130 READBI P8,Q8 FROM @0,TA,SA
3140 READBI P9,Q9 FROM @0,TA+1,SA
3150 IFDTM @0,"UNP"
3160 RETURN
4000 REM SUB FOR #1
4010 NORMAD WA,WB,WC,Z1,VT
4020 PAGE\
     GRAPH WC\
     SMOVE 300,750\
     PRINT "SIGNAL FROM INSTRUMENT #1"
4030 WAIT
4040 DELETE WP
4050 RETURN
5000 REM SUB FOR #2
5010 NORMAD WA,WB,WC,Z2,VS
5020 PAGE\
     GRAPH WC\
     SMOVE 300,750\
     PRINT "SIGNAL FROM INSTRUMENT #2"
5030 WAIT
5040 DELETE WP
5050 RETURN
```

END

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DTIC